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CONTENTS

Public Opinion and World Affairs . . ANDREW GYORGY 131

Notes on the *Report of the Committee on Policies in Graduate Education* . JOHN L. FLETCHER, JR. 137

Scientific Computation and Numerical Analysis . . . . . FRANCIS J. SCHEID 140

The African Research and Studies Program . . . . . ELIZABETH COLSON 150

The Relation of Electrochemical Potential to the Degree of Sintering . . BENNETT BOVARNICK 154

Book Reviews 160

The Modern Researcher, by Jacques Barzun and Henry F. Graff
A Guide to Graduate Study, ed. Frederic W. Ness

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Public Opinion and World Affairs*

ANDREW GYORGY

Professor of Government, College of Liberal Arts

IT is both a pleasure and an honor for me to be able to appear tonight in front of you and deliver the keynote address of this highly successful Anniversary Conference of the S.P.R.C. of Boston University. As the late Wendell Willkie remarked when accepting the Presidential nomination, "I feel both humble and proud."

As a political scientist, I had to redefine the terms of this challenging assignment. It would be suicidal for me to get enmeshed in the highly refined terminology of the modern communications arts or of the science of public opinion research. Indeed, such foolhardiness would merely conjure up a latter-day image of the great Catholic philosopher Jacques Maritain, who in the spring of 1933 first appeared at the University of Chicago. There, he wrote recently, "I gave my first lecture in English without knowing yet a single word of this language."

The only valid approach to the topic of tonight is to weave communications and public opinion into a forceful and timely discussion of world political problems. The most fundamental assumption of all is a recurring emphasis on the organic inter-relationship between our two fields: both the experts in public opinion and the students of international politics are lifelong and professional communicators filling curiously interlocking roles and assignments. "Now you see us, now you don't," as we quickly change costumes between alternating roles or different acts of basically the same play. To borrow an apt analogy from contemporary architecture, ours is probably the happiest split-level arrangement of mid-twentieth century social science: politics and the communication arts merge naturally and harmoniously at most junctures or crossroads of our inter-disciplinary world. As long as the "split-level" ap-

*An address delivered April 11, 1958, to the Tenth Anniversary Conference of the School of Public Relations and Communication.

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proach remains an architectural, and not a psychiatric proposition, all of us are reasonably safe.

A further significant similarity should be pointed out here. Public opinion and communications research have only recently acquired the status of a true "science"—as a result of the massive and exciting research developments of the last ten or twelve years. The same generalization also holds true of our discipline: since the end of World War II the theory and practice of International Politics have achieved a similarly lofty position within the hierarchy of the major social sciences. It is a pleasure to record, therefore, that both of us have been keeping good company in recent years.

In order to engage in a broad stock-taking process here tonight, let me go back briefly to where we stood ten or twelve years ago, and reflect in passing on what our principal problems and concerns seemed to have been at about the time when Boston University first launched its new School of Public Relations.

That was the era of hopeful over-simplifications and exuberant generalizations in our respective fields. We kept talking about world government, world federalism, and about a tangible IPO factor (International Public Opinion) in international relations, as if it were a well-crystallized force in world politics. In categorical terms we drew sweeping social conclusions. Former Assistant Secretary of State Adolph Berle wrote, for example, that "priests are usually able to intimidate the policemen, while philosophers can usually check the politicians." Today's more discriminating student would undoubtedly note that the politicians are distinctly unchecked, while the policemen appear to be quite unintimidated. In international politics we emphasized the "universal appeal" of certain public opinion values and political attitudes; truly, the 1946-1950 period—particularly in retrospect—seems to stand out as the age of the aggressive "sloganophiles" and as the "finest hour" for real globaloney.

Two other general attitudes plagued American public opinion at the same time, both startlingly rigid and inflexible. On the one hand it was much too conscious of the complete bi-polarity of world politics, of the deepening chasm between East and West and the lengthening shadow of the Cold War, while on the other it indulged in a peculiar, and often semi-hysterical, black-and-white thinking on the great issues of world affairs. The spring and summer of 1946 offered a whole set of such clinically most interesting displays. Great exultation over the birth of the U.N. was followed by the first Soviet veto in the Security Council, and by Winston Churchill's historic warning in the Fulton, Missouri, speech. In turn, the fairly successful peace treaty negotiations at the Paris Conference had their own depressing anti-climax in a series of ugly Balkan incidents which, at one point, brought us to the brink of war with Tito's Yugoslavia.

Throughout these political spasms, public opinion jumped from inflexibly "all white" (exultant) reactions to the depth of "all black" (depression-type) emotions, clearly resembling the unhappy fever chart of a very sick malarial patient. But one positive feature did emerge: we gradually began to discern the permanent dichotomy between Communism and Democracy. Here was the birth-place of two significant new types of theories in the field of modern communication: the Marxist-Leninist-Stalinist approach to a manipulation of the Communist propaganda system, and the "social responsibility" principle of a democratic communications network in a free world setting. The reason for their emergence in the early post-war period was rather obvious: the simultaneous development of mass production and mass government was bound to promote a significant rise in mass communication to form, direct, and influence public opinion. Since both democratic and totalitarian governments depend upon mass support, in the stalemate of a cold war the truly ideological battle will be fought with specially developed mass communications media loaded with propaganda content, and feverishly aimed at the development of a favorable public opinion atmosphere. As one authority recently remarked: "International negotiations, once the exclusive concern of selected diplomats in private meetings, are today carried on by public debate and special delivery letter."

Without being able to explore fully at this point the intricacies of a democratic vis-à-vis totalitarian theory of mass communications, two additional features of the early post-war period must be stressed here. All of us were probably much too Western Europe-conscious and oriented at that time. While it is evident that two important European salvage operations (more formally known as the Truman Doctrine and the Marshall Plan) had been successfully launched and brought to full fruition, we did nevertheless shamefully ignore the problems of the less developed (or undeveloped) areas of the Middle East, of Asia and Africa—and lived to regret this sin of omission at a later date in world history. Recent Soviet diplomatic successes, both of the economic and cultural variety, can clearly be ascribed to Western, and particularly American, indifference during a crucial period when a number of key countries could have naturally gravitated toward our side.

We also deserve strong castigation for being much too producer-conscious, and not sufficiently imbued with consumer-conscious drives and ideas. We are returning here to a more moderate consideration of the IPO factor—we do indeed have a selling job of world-wide dimensions to perform. We have neglected to carry out this job! In a gimmick-conscious age it seems easier and pleasanter (and also more rewarding) to sell soap instead of democracy. When Soviet experts in public relations and mass advertising, clearly comparable to our own people in ability and experience, are busily engaged in selling Communism, we must recast certain easy-going and de-

ficient national modes of behavior, and set out aggressively to prove "why" and "how" our system is superior to theirs.

Instead of vaguely moralizing, however, we ought to take stock now of certain recent trends, issues, and problem areas in our two fields. By far the most towering development of the past decade has been the emergence of a full-fledged "Communication Revolution." This is not just a trend, or a minor quantitative variation on a theme, but a qualitative *and* dynamic change! Instead of a mere "innovation," we can truthfully talk in terms of a "revolution." Professor Daniel Lerner of M.I.T. correctly defined for us the end product of this revolution as the massive appearance of a World Communications Network. Since around the world twenty-five million new literates enter the global network each year, this has been a predetermined and inevitable revolution from the start. Its most noteworthy characteristic has been the phenomenal increase in peoples' psychic mobility all over the world, acquired through the press, radio, movies and TV, long before they were in a position to increase their physical or social mobility. The resultant instability, in turn, directly affects the political system of individual nation states, and produces more-or-less latent socio-political tensions, crises, and instabilities on the home front. No wonder that dictators, Communist or otherwise, were the first ones to grasp the multiple new opportunities so tantalizingly offered by this "Communications-Revolution."

Listen, for example, to the strident voice of Colonel Nasser, new President of the recently formed United Arab Republic. In January 1957 Nasser observed: "It is true that most of our people are still illiterate. But politically that counts for far less than it did twenty years ago. Radio has changed everything. Today, people in the most remote villages hear of what is happening everywhere and form their opinions. Leaders cannot govern as they once did. We live in a new world."

From a strictly political perspective, I would describe this new world as one of hedge-hopping nationalism. The bi-polar world of the nineteen-forties is gone and extinct forever. The incessant chain-reaction of the explosions of political nationalism has first created a tri-polar pattern which, more recently, evolved into some sort of a polycentric world centered around multiple groups of nations. This is a world of newly emerging federations, of processes of economic integration, of bloc voting (inside or out of the United Nations), of Afro-Asian or Bandung groups of states. Nationalism has ceased to be a national phenomenon, and instead has mushroomed into a set of regional products. It hedge-hopped across the previous boundaries of the single sovereign state, and now faces a much broader horizon. In the image of a modern Frankenstein, it has grown beyond the recognition of its original creator. Franklin D. Roosevelt, who so confidently called for the "quarantining of the aggressor" in October 1937, would have a hopeless task in attempting to de-

fine today the person of the aggressor and the possible locale of the expected act of aggression. How can one quarantine two-thirds of this more-or-less civilized world?

In sum, the student of communications and public opinion must keenly realize that the shrinking world he confronts is one of multi-national constellations fused by a spirit of regionally projected nationalism. It is a highly precarious world heralding both the end of a chapter (the death and legacy of great empires), and the beginning of another era which may well usher in a set of new empires in a Middle Eastern or South East Asian setting. Although certain imperial fires have definitely been banked for all time, others are already glowing above the not-too-distant horizon. Once again, we find ourselves living in an era of transition which someone correctly defined recently as leading from one period of transition to another one.

The concept of "hedge-hopping nationalism," of intense interest I trust to all of us, is not incompatible with the central political phenomenon of our times, the worldwide political institution of contemporary totalitarianism. The distinguished French sociologist, Raymond Aron, may have been wrong in one of his fine recent works, *The Century of Total War*. Quite possibly, our century will be remembered as the Century of Totalitarianism. Although limited in number, our clinical case studies range from Franco to Batista to Menderes on the political right, and from Khrushchev to Mao to Tito and Gomulka on the left. Totalitarianism, implying total government within a totally controlled and monopolized social framework, is indeed the cancerous political growth of the mid-twentieth century, which should occupy the primary attention of students of communication and political science alike.

Of all the malignant forms of modern total government, Communism is undeniably by far the most sinister and dangerous. What should concern us most is its fatal attractiveness to large and, politically speaking, increasingly important areas. Earlier in this discussion we have alluded to our neglect of the consumer, whether new or old, and to our multiple sins of omission in key non-European areas. Now we must point to two other, and yet closely related, recent phenomena. One is the rising tide of anti-Americanism, another the diabolical cleverness of our opponent in the Cold War. Anti-Americanism is not solely a Communist creation, and its harmfulness should be neither exaggerated nor ignored. It frequently feeds on our own wrong approach to foreign problems or on the "selling" of wrong ideas. Can or should we export our own brand of the "economics of welfare"? How exportable are some of our criteria and standards, particularly a single-minded belief in the material aspects of our national standard of living? Are we not suffering from a collective "brontosaurus principle," so ably defined a few years ago as "the overall disadvantage of immense size" by Professor Kenneth Boulding in his *The Organizational Revolution*?

The other peril-point is the increasingly clever, cunning and highly articulate propaganda warfare conducted by the omnivorous Agitation-Propaganda (Agitprop) sectors of Khrushchev's recently revamped Soviet government. The new Prime Minister's approach to *Agitprop* is vastly different from Stalin's methods of global political warfare. Khrushchev's position of strength lies in the skillful combination of flexible short- and long-term diplomatic strategies with an insistence on the realization of certain Communist-coined so-called "permanent laws of human destiny," such as the inevitable victory of Communism in the course of the twentieth century. Thus, on the one hand he and his colleagues can exploit the "ebb and flow," the "advance and retreat," the "tactics and strategy" of a given ideological situation, while on the other they cleverly play up and promote a few cheap propaganda gimmicks into allegedly ironclad laws of "human development." Exploiting the utter illogic of totalitarian politics, Khrushchev and Company seem to convey to us one peculiar, although not original, public relations message: "Nothing exceeds like excess!"

We, on the other hand, have been plagued by a disturbing and none-too-justifiable inferiority complex, as if we all knew and were convinced that mass communication was important and here to stay, but not really certain that it was also socially responsible. This innate hesitancy of a democratic society is nothing new or startling. Its strongest and most persistent critic has been Walter Lippmann, who in his *The Public Philosophy*, recently described public opinion as "the malady of democratic states.... The prevailing public opinion has been destructively wrong at the critical junctures.... Mass opinion has acquired mounting power in this century. It has shown itself to be a dangerous master of decision when the stakes are life and death."

But let us not engage here in gloomy post mortems on the recent successes of our Communist adversary. On this pleasant occasion let us, on the contrary, reaffirm our strong belief that even the most tightly closed "captive mind" can be pried open with an intellectually and emotionally sound system of communications. Let us not be intimidated or expropriated by the multiple ideological fallacies of "total" politics or "total" societies. No man-made Iron Curtain can be impervious to the simple fact of Truth, nor can Iron Curtains mushroom endlessly in the political world of today. Nazis can be denazified, defectors can redefect, nomadic peoples can be denomadized, but —happily for all of us here—truth cannot be de-verified.

In conclusion, I would like to offer a shining illustration of this secret weapon of the free world. A few days ago more than 3000 individuals from 108 different nations—including Iron Curtain countries—participated in an essay contest on "What World Brotherhood Means to Me." The contest was sponsored by the World Brotherhood organization, international arm of the National Conference of Christians and Jews, and U.S.I.A., the United States

Information Agency. While the prize-winning essay was written by an African policeman from Accra, Ghana, one hundred and eleven signed, formal entries came from behind the Iron Curtain, many of them giving addresses, ages and occupations. (Think of those people's courage!) An entry from a woman in Poland included this pronouncement: "World brotherhood is a power which makes possible for humanity to be victorious over evil and ignorance."

This, indeed, is a free spirit's reply to the Orwellian nightmare of the "Big Brother" image, so effectively conjured up by contemporary Communism. Furthermore, ladies and gentlemen, could you think of a more dramatic seventeen-word statement of what all of us are eventually striving for?

Notes on the *Report of The Committee on Policies in Graduate Education*

JOHN L. FLETCHER, JR.
Associate Dean of the Graduate School
Associate Professor of Government, College of Liberal Arts

FOUR graduate school deans, comprising the Association of Graduate Schools' Committee on Policies in Graduate Education, have made a frontal assault on the pinnacle of American education — the doctor of philosophy degree — and have thereby performed a real service.* The Committee's report has been widely publicized — the *New York Times* printed the full text on November 13, 1957 — and it will stimulate considerable rethinking of the ends and means of graduate education in the arts and sciences.

The Committee's chief bone of contention is what it calls the "make believe" element of the Ph.D. degree. This is the assumption that award of the degree signifies that the recipient can lecture and write successfully. In the Committee's opinion this assumption is a myth, for Ph.D. candidacy hinders, instead of nourishes, the development of these skills. The Ph.D. thesis, and the misplaced emphasis on length and quantity of footnotes instead of on originality and style; the stress on routine courses as opposed to individual study; and the lack of adequate faculty guidance, both at the time of initial registration and when the thesis is outlined, are all cited as debilitating factors.

Particular attention is given to the uncertainties in the Ph.D. program,

*The members of the Committee were Dr. Marcus A. Hobbs of Duke University, a chemist; Dr. A. R. Gordon of the University of Toronto, also a chemist; Dr. J. P. Elder of Harvard University, a classicist; and Dr. Jacques Barzun of Columbia University, an historian.

especially that of the length of time required for its completion. The period for professional training in law, medicine, and business is fixed, but Ph.D. candidacy may stretch on *ad infinitum*. The following statistics for the period of candidacy for sixty survivors who were awarded the Boston University Ph.D. at Commencement in June, 1957, indicates that the Committee's generalization was not unfounded.

DURATION OF PH. D. CANDIDACY
AT BOSTON UNIVERSITY

*Statistics for Sixty Graduates in June, 1957**

Length of Candidacy	*Number of Graduates*
Two years	3
Three years	9
Four years	15
Five years	8
Six years	8
Seven years	1
Eight years	8
Nine years	3
Ten years	2
Eleven years	1
Twelve years	1
Thirteen years	1
Total Number of Graduates	60
Average period of study per graduate	5½ years

*The high average at Boston University can be explained in part by the fact that many candidates do much of the work for the doctorate on a part-time basis. On the other hand, it should be noted that the Master's degree must be completed before candidacy for the Doctorate may be begun. The figures in the table include only the period of graduate study *after* the Master's degree.

It would be a mistake, however, to infer that the report's primary concern is with the excessive length of study for the Ph.D. degree. On the contrary, its major preoccupation is with academic values, or standards, and in particular with the quality of the Ph.D. degree. The purpose of the degree must be clearly defined. Too often, says the Committee, the new Ph.D. emerges from his studies "spiritually dried up."

> The desire for finding out what had not before been known, the imaginative urge to reinterpret—these the tired and weary student has gradually lost. He has been wrung dry, and, knowingly or not, he often finishes his thesis with the firm resolve to have no more to do with 'scholarship.' The drive—almost the poetic drive—which first excited him and sent him on from college to graduate school is now run out.

The possessor of the Ph.D. should be

> a man who combines wide-range learning with an attitude of simplicity and vividness, and who commingles good taste with an excited curiosity...[The Ph. D.] implies a high technical ability—and...taste and skill in the art of written and oral communication.

And how is the attainment of these objectives to be assured? A number of specific proposals are made. Admission standards within a candidate's

own field must be tightened. In particular, the Committee holds that the candidate should be able to write respectable English and suggests that he be required to take an examination in the writing of English prose at the time of initial registration. Also, the Committee stresses the importance of satisfying the foreign language requirements early and recommends that a candidate be required to pass examination in at least one language at the time he first registers, the second language requirement to be fulfilled by the end of the second year at the latest. The Committee also suggests required courses in research methods and in extensive reading and writing. There are other suggestions as well. In combination, all of the recommendations point toward the Ph.D. as a sign of wide learning, technical skill, writing style, and originality.

That the criticism of current practices in Ph.D. programs is well-founded can easily be demonstrated. All too often the Ph.D. program is deficient in those respects the Committee deems most important. The report, therefore, must be judged highly successful as a statement of critical evaluation. But what of its worth in a more positive way? What does it contribute toward a solution of what it has described as "the starkly pressing demand for Ph.D.'s"? In this respect the report is sadly lacking. Despite the Committee's concern with the length of time for obtaining the Ph.D., its recommendations would be of little help in increasing the supply of Ph.D.'s. Despite the merits of the proposal on other grounds, the general tightening of standards which the report advocates would diminish, not increase, the supply of Ph.D.'s.

The Committee may have recognized its failure to meet the major national need for an increased supply of college teachers, for, almost as an afterthought, it ended the report with an abbreviated section on the M.A. degree. The report suggests that the M.A. course of study should differ from that of the Ph.D. only in duration, not in quality. Under its proposal the M.A. program would take one and one-half years. But once again the Committee fails to face the problem realistically. The quality and level of prestige of the M.A. is already too well established to permit the radical up-grading of the degree proposed. The fact that the M.A. degree is more important in the preparation of secondary school teachers than college instructors has apparently been overlooked.

In regard to other more minor aspects, one cannot help but wonder about the Committee's orientation. The inflexibility of its proposals regarding the language requirement — the assumption that two foreign languages must be required and that German will be one of the two — bespeaks the viewpoint of the humanists. Could it be that the two chemists — a more pragmatic approach would have been anticipated from them — were taken in by the stylistic elegance and wit of their fellow committee members?

Scientific Computation and Numerical Analysis

FRANCIS J. SCHEID
Professor of Mathematics, College of Liberal Arts

(*Continued from the April issue*)

Iterative methods have also proved effective in the solution of equations, a study which goes far back into history. Certain quadratics are found in Diophantus and in various Hindu writings. The general quadratic

$$aX^2 + bX + c = 0$$

was solved by the Arabians, essentially in the form we use today

$$X = (-b \pm \sqrt{b^2 - 4ac}) \div 2a$$

The solution "reduces" the problem to root extraction and arithmetic. Higher "degree" equations were studied in Babylonian times. Omar Khayyam used a geometric method for solving certain types. To illustrate his approach, which is still in common use, we take the cubic

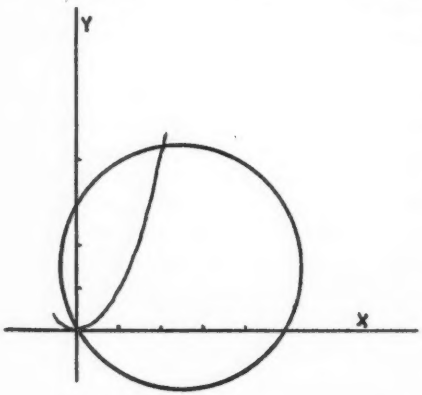
$$X^3 = 2X + 5$$

and replace it (the algebra is easily checked) by the two equations

$$Y = X^2$$

$$X^2 + Y^2 - 5X - 3Y = 0.$$

These may be interpreted geometrically as a parabola and a circle. The two curves intersect at $X = 0$ and near $X = 2.1$, and one may easily verify that the latter value makes the above cubic almost true. Omar's method applies only to cubics and quartics of certain type. Once the parabola has been accurately sketched it can be used for all such problems. The circle depends upon the particular equation, but circles are easily constructed. Only a few digits could be found by this method.



In 1247 Ch'in Chui-shao wrote the "Nine Sections of Mathematics." It includes a problem which leads to a tenth degree equation, and introduces a successive digit method similar to what is now known as Horner's method. For the simpler equation

$$-X^4 + 763200X^2 - 40642560000 = 0$$

Ch'in Chui-shao first finds the leading digit 8 (hundreds) and then trans-

forms the equation to facilitate finding the next digit, which turns out to be 4 (tens); the root 840 quickly appears. Isaac Newton (1669) used a similar procedure to find to eight decimals a root of $X^3 = 2X + 5$.

In the sixteenth century, the Italians Tartaglia and Ferrari reduced third and fourth degree problems to the extraction of cube roots and fourth roots, just as the Arabians had much earlier solved the quadratic. Their formulas, however, sometimes require the use of "imaginary" numbers even to produce "real" roots. Fibonacci (1225) gives the root 1.368808107 of the cubic $X^3 + 2X^2 + 10X = 20$. No one knows how he obtained it, but it is correct to nine decimal places. We shall use this equation to illustrate an iterative solution process, rewriting it first as

$$X = \frac{20}{X^2 + 2X + 10}$$

A slowly converging sequence of iterations.

1.000000000
1.538461538
1.295019157
1.401825309
1.354209390
1.375298092
.....
1.368808486
1.368807940
1.368808181
1.368808075
1.368808122
1.368808101
1.368808110
1.368808107
1.368808107

and setting up the iteration

$$X_{k+1} = \frac{20}{X^2_k + 2X_k + 10}$$

Taking $X_1 = 1$ we find a sequence of approximate solutions whose "convergence" to Fibonacci's value is painfully slow. Twenty-six iterations are required (see accompanying list) to obtain nine correct decimals. Here (and elsewhere in modern computing) there is a need for "acceleration." And an acceleration method has been found. It is based on the fact that consecutive errors decrease like powers of some number A, or approximately

$$k\text{th error} = X - X_k = B \cdot A^k$$

It is not necessary to find the numbers A and B; instead this equation may be written for three consecutive values of k; elementary algebra then suffices to eliminate A and B and yield

$$X = X_{k+2} - \frac{(X_{k+2} - X_{k+1})^2}{X_{k+2} - 2X_{k+1} + X_k}$$

This formula may be applied whenever three values X_k, X_{k+1}, X_{k+2} are on hand. For the equation of this paragraph we find (with $k = 10$) the same value as X_{25}, thus saving thirteen iterations. Applying the acceleration device earlier and periodically would save even more steps.

Many other iterative procedures exist, some of them even faster than our accelerated one. But the technique is not foolproof. If one rewrites the equation of this example as:

$$X = (20 - 2X^2 - X^3) \div 10$$

and attempts a similar calculation, the failure becomes evident very quickly.

Plausible schemes sometimes succeed, but — what is more important — they often fail. One cannot rely upon intuition in these matters.

No one knows how long Fibonacci required to solve his cubic equation. A tiny fraction of a second would suffice today. Equations of degree 100 or more have been solved often to find critical vibration frequencies or critical loads. There is, however, room for improvement in technique. It will be readily believed that finding all the roots of

$$X^{1492} + 1066\,X - 1620 = 0$$

(there are 1492 of them) would involve quite a piece of computing. Fortunately this problem has not yet arisen in applications.

Almost everyone recalls the experience of solving two simultaneous linear equations such as

$$2x + y = 5$$
$$x + 4y = 6$$

during his studies of beginning algebra. This is a case of "two equations in two unknowns" or a linear system of order two. The method of solution may have been as follows:

1) multiply second equation by two
2) subtract first equation from result
3) use new result to replace second equation

The original system has then been changed to

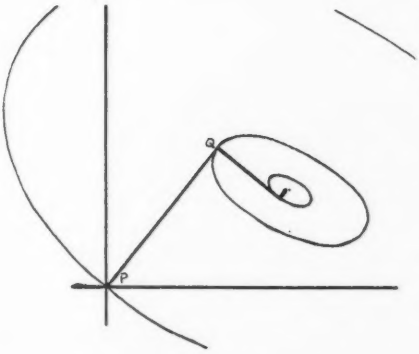
$$2x + y = 5$$
$$7y = 7$$

which is of "triangular" form, and is now solved from bottom upwards by "back substitution."

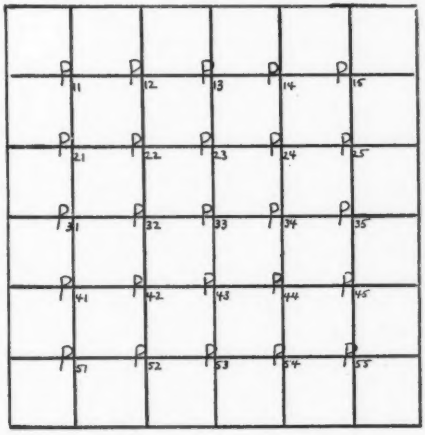
It is of some interest that this elementary method of reduction to triangular form, apparently used (for order 2) by Sun-tzi around the first century, is still one of the best available, even for the systems of high order which now arise every day. Many improvements have been made in it, but the basic idea remains a major tool of most computing laboratories. Hundreds of alternative methods have been discovered, and it is doubtful that there will ever be general agreement on which is best. In certain cases iterative methods have a distinct advantage. A whole class of iterative techniques is based upon an equivalence between linear systems of order N and the problem of finding the center of an N dimensional "ellipse." For our system of order 2, the ellipse is two dimensional and is represented by the equation

$$x^2 + 2y^2 + xy - 5x - 6y = \text{a constant.}$$

Starting from an arbitrary point P (or first approximation) we choose a direction and follow it to a point Q (or second approximation). The direction of the center itself is of course unknown but there are several ways of sneaking up on it.



A scheme familiar to Cauchy (1847) consists of choosing the direction perpendicular to the ellipse and proceeding to the point of tangency with a "parallel" ellipse. Repeating, a zigzag path is followed which approaches the center by an infinity of shorter and shorter steps. This is the method of "steepest descent." Its convergence is often too slow and acceleration procedures have been found. It is a remarkable discovery of this decade that by properly choosing directions the center can be reached in N steps. This means that in our example, having arrived at Q, the direction of the center can be determined, and the endless succession of zigs and zags is avoided. Known as the "method of conjugate gradients," this seems to be one of the best now available in spite of the fact that the theoretical exact "hit" on the Nth step is spoiled by the impossibility of carrying out the process exactly.



Still another approach to the linear system is by "Monte Carlo" methods. Suppose that a dog is lost in a maze of corridors. He chooses a corridor at random and follows it to the next intersection, where, he again chooses at random and so on. If he emerges at the north side he is to be fed, otherwise not. The problem: "What are his chances of being fed?" If this probability (of being fed), which varies from one intersection to another, is denoted as in the diagram by P_{11}, P_{12}, etc., it is not hard to show that each probability must be the average of its four neighbors. For instance

$$P_{22} = \tfrac{1}{4} [P_{12} + P_{21} + P_{23} + P_{32}]$$

and

$$P_{11} = \tfrac{1}{4} [1 + 0 + P_{12} + P_{21}]$$

where 1 represents the certainty of being fed at the north boundary point and 0 the certainty of not being fed at the west boundary point. If such equations are written for all interior points we have a linear system (of order 25 for the maze shown).

But it is known that this same system is a good approximation to various problems (of hydrodynamics or electromagnetic theory or heat transfer) involving the Laplace partial differential equation

$$\frac{\delta^2 P}{\delta x^2} + \frac{\delta^2 P}{\delta y^2} = 0.$$

It is therefore possible to solve problems of theoretical physics approximately by losing dogs in mazes and counting the numbers emerging at the various boundary points.

The same effect is obtained more quickly by programming a high speed calculator to execute the random walk. The basic step is the automatic generation of random numbers (say between 0 and 1) by the computer. But how can a machine choose numbers at random?

To illustrate an efficient method let us imagine a two-decimal-digit machine. The steps are:

1) Select an initial "random" number, say .01.
2) Multiply by some fixed number m.
3) Of the four-digit product take the last two digits as the next random number.
4) Repeat steps 2 and 3 again and again.

For example, if m = .05, we find the sequence

.01, .05, .25, .25, etc., etc., etc., etc,

which is far from random in any sense. The choice m = .05 was a bad one for this machine; m = .13 would have been much better. Good choices for various machines have been found and are available in the mathematical literature. For SEAC, the Bureau of Standards Eastern Automatic Computer, $m = 5^{17} \cdot 2^{-42}$ is excellent, which means that it produces a sequence of "uniformly distributed" numbers between 0 and 1. (If this range is subdivided into equal parts, for example into quarters, then the members of the sequence fall impartially into the subdivisions. Of 1000 numbers roughly 250 would be in each quarter.)

We return now to our random walk and draw a number from the uniform distribution. If it falls between 0 and ¼ a northward step is made, if between ¼ and ½ an eastward one, if between ½ and ¾ a southward one, and so on. After each step the computer checks to see if a boundary has been reached. If not, it continues the walk; if so, it starts another walk, or perhaps stops. Thousands of steps can be made every second. Even so, results come slowly. Many thousands of sample walks are required to give a few correct decimal places. In an experiment on SEAC the following typical results

were obtained at three arbitrarily chosen points. Correct values are also listed for comparison.

No. of samples	*1st pt.*	*2nd pt.*	*3rd pt.*
512	.2813	.7559	.9727
1024	.2813	.7549	.9766
1536	.2865	.7677	.9766
2048	.2861	.7642	.9741
2560	.2863	.7677	.9742
3072	.2835	.7686	.9736
3584	.2879	.7681	.9749
4096	.2890	.7679	.9751
4608	.2908	.7639	.9740
5120	.2918	.7672	.9744
5632	.2940	.7669	.9806
6144	.2922	.7655	.9744
6656	.2910	.7665	.9749
Correct values	.2932	.7672	.9732

About five million samples would be needed to obtain four correct decimal places, showing the desultory nature of the convergence. Fluctuations of this sort are the rule and have inspired many efforts to produce acceleration or (as professional Monte Carloists prefer to say) variance reducing devices. In spite of the slow convergence there are circumstances which may warrant a Monte Carlo approach to a linear system, perhaps where only one unknown is needed and that to only a few figures. In some cases the random numbers needed should not be "uniform." That is, more should fall in some ranges than in others. A few techniques have been found for sampling from such non-uniform distributions. A "rejection" method is also popular. Here one generates a uniform random number and then accepts it or rejects it according as a supplementary test succeeds or fails. Too high a rejection rate means low efficiency and long computing time.

Linear systems are among the most frequently occurring computational problems of our time. Orders fifty to one hundred are commonplace and a system of order 2300 was solved for the U. S. Coast and Geodetic Survey. The treatment of high order systems has exposed one of the major problems of modern numerical analysis, the "round-off error." For example, when a device capable of handling let us say ten digit numbers, performs a multiplication of two such numbers, it can retain only 10 digits of the product. The resulting "round-off" involves a small error.

$$\begin{array}{r} .1234567890 \\ .3333322222 \\ \hline .0411521258(2304651580) \end{array}$$

In short calculations this may not be serious, but in solving a system of order 100 a million multiplications may be carried out. One would indeed be optimistic to say that the million round-offs were of no consequence. The analysis of round-off effects is not easy and has been done satisfactorily for very few situations; it is a major challenge for current researchers.

Even with low orders, one occasionally encounters troubles. There are "ill-conditioned" systems for which all known methods fail. The nature of the difficulty may be partly understood by limiting all numbers to one decimal place and trying to solve the equations

$$x + .8y = 1$$
$$.4x + .3y = 0,$$

only to encounter an obstacle such as

$$0 = .4,$$

which is nonsense. Computers, whether human or machine are, of course, seldom limited to one decimal place, but systems have occurred in actual practice for which no computer in existence can carry sufficient places to avoid this very same difficulty. Ill-conditioning is a much-discussed topic among numerical analysts, and methods for improving the condition of a system are developing.

The preceding problems all have long histories. For solving them the methods of rough approximation sufficient for the ancients have yielded to iterative methods or infinite processes capable of producing the many decimal digits so often desired today. Two examples of more recent origin will now be given.

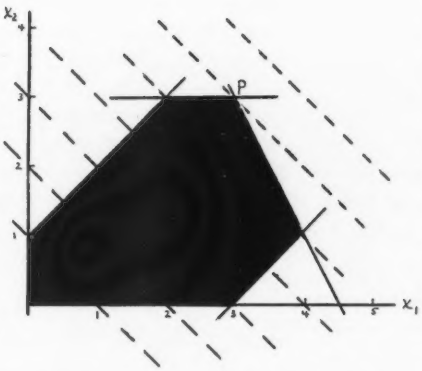
In such fields as economics and military strategy the question arises, when does a quantity such as

$$A_1x_1 + A_2x_2 + \cdots + A_nx_n$$

take its maximum value, if it is essential that certain related quantities

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1N}x_N + b_1$$
$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2N}x_N + b_2$$
$$\cdots\cdots$$
$$\cdots\cdots$$
$$a_{k1}x_1 + a_{k2}x_2 + \cdots + a_{kN}x_N + b_k$$

all be greater than or equal to zero? Perhaps the problem is to maximize the profit in a certain operation subject to limitations of production, storage, labor, or demand. Usually the number of variables is fairly large, but to see the basic facts rather easily suppose we deal with just two variables and seek the maximum value of $x_1 + x_2$, with the limitation that the six quantities x_1, x_2, $-x_2 + x_1 + 1$, $-x_2 + 3$, $-x_2 - 2x_1 + 9$, $x_2 - x_1 + 3$, shall not be negative.



A geometric reinterpretation here leads to a clear view of the problem. The six limitations force the point (x_1, x_2) to lie on the proper sides of six straight lines and so in the shaded area of the diagram. Maximizing $x_1 + x_2$ then amounts to choosing from the family of dotted lines the particular one which

(a) touches the shaded area in at least one point

(b) is farthest from the origin O.

The solution is easy to find in our little problem. It is point P, where x_1 and x_2 are both equal to 3.

In a more complicated case our shaded area would become a many-dimensional polyhedron and the solution could not be seen so quickly. One fact stands out, however. The solution must occur at a vertex. So, by following a path along the edges we can expect eventually to find the solution vertex. Of course the work would not be done geometrically, but arithmetically, dealing directly with the basic formulas. Modifications of the procedure just (very crudely) described and alternatives to it have been attractively entitled the simplex method, fictitious play, and the relaxation method.

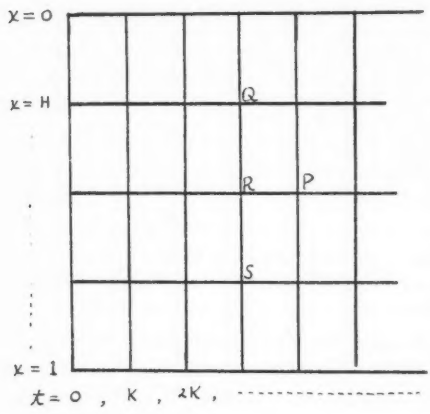
A final example, again of recent origin, involving slightly more sophisticated mathematics, can be drawn from the field of fluid dynamics (the same mathematical situation also arises in heat conduction and other problems). One may be required to treat the partial differential equation

$$\frac{\delta u}{\delta t} = \frac{\delta^2 u}{\delta x^2},$$

where u denotes fluid velocity (which differs from point to point), and the symbol $\frac{\delta u}{\delta t}$ represents the rate at which u changes with time at a particular point. A natural way of approximating this rate is to measure u at two moments, as close together as possible, and to divide the difference in u by the time interval. This gives the "average rate" so familiar to all students of elementary algebra ($D = RT$). The symbol on the right also denotes a rate which may be similarly approximated. This procedure is known as a method of "finite differences." One would suppose that with sufficiently short intervals, the approximate rates are for all "practical" purposes adequate. But such is not the case. The analysis of this phenomenon is more

technical than the present paragraph hopes to become, but the conclusion of the numerical analyst is that unless certain (nonintuitive) requirements are obeyed the numerical results will bear no resemblance whatever to the mathematical or physical facts.

To be a little more specific, suppose that we have a layer of fluid at rest between two large parallel flat plates one inch apart. One plate is now put in motion with speed 1. How does the fluid respond? Our equation serves as a pretty good mathematical model of this physical problem, where x is distance measured across the layer. It is very convenient to use a geometric layout in which time is plotted in one direction and x in the perpendicular as shown in the accompanying figure. Various equally spaced lines (horizontal separation K, vertical separation H) have been included. The type of approximation suggested above restricts the search to the values of fluid velocity at the intersection points, and leads to the (not too hard to deduce) equation



$$P = rQ + (1 - 2r)R + rS,$$

where P, Q, R, and S are fluid velocities at the points indicated, and $r = K \div H^2$. Since the boundary velocities are known ($u = O$ at top, $u = 1$ at bottom, $u = 0$ at left) it is not hard to see that this equation permits the calculation of all other values, first for $t - K$, then $2K$, and so on.

Let us take $H = \frac{1}{4}$ for simplicity. Any other value would do. It remains to choose r. For the two choices $r = \frac{1}{2}$ and $r = 1$ the numerical results are shown to three decimals up to $t = 6K$.

$r = \frac{1}{2}$

0	0	0	0	0	0	0
0	0	0	.125	.125	.188	.188
0	0	.25	.250	.375	.375	.438
0	.5	.50	.625	.625	.688	.688
1	1	1	1	1	1	1

$r = 1$

0	0	0	0	0	0	0
0	0	0	1	−2	6	−14
0	0	1	−1	4	−8	21
0	1	0	2	−2	7	−14
1	1	1	1	1	1	1

The first table is not too unrealistic, but it takes no hydrodynamicist to suspect that something is wrong with the second. Indeed, here we have an example of what has been termed "numerical instability." The value $r = \frac{1}{2}$ is the largest "safe" value we can use. Trying to march forward in time too quickly we lose everything. In other areas of partial differential equations the same effects may be observed, and this part of numerical analysis has been under heavy study.

A vital companion question asks whether choosing H and K smaller and smaller, thus working harder and harder, produces results which are closer and closer to the true values (of fluid velocity). That is, does the numerical method "converge"? The question has been answered, at least for many of the problems currently arising, and in the affirmative. But again there are qualifications and "be careful not to's."

Many other types of problem are being put through today's calculating devices, from the deployment of submarines to the design of industrial or agricultural experiments. For all of them numerical analysts have produced methods of attack. The search continues for better methods, and for any method at all with which to attack problems which are not being run on today's computers because no one knows how to solve them. Often a plausible scheme is tried out, and fails. The computer has become a piece of experimental apparatus. The mathematician has long been the fellow who requisitions nothing but pencils and paper. He need no longer apologize to his colleagues in science. The electronic calculator is his million-dollar instrument.

The African Research and Studies Program

ELIZABETH COLSON
Research Associate, African Studies Program
Associate Professor of Anthropology, College of Liberal Arts

SINCE the end of the Second World War, the continent of Africa has become increasingly prominent on the international scene. Its people are demanding greater participation in their governments. In some regions they are demanding independence or as in Ghana have already achieved full nationhood. The Bandung Conference and the more recent meeting at Cairo of representatives of Asiatic and African nations are indications of the change in the world political balance resulting from the emergence of former colonial possessions into political independence. Accompanying the drive for political advancement has been a sharp emphasis upon economic development.

Everywhere throughout the continent there is the stir of change accompanied by growing nationalism, industrial development, and the rise of urban populations which are radically altering old institutions and old values. In some regions, the change is complicated by the clash of interests between European and Asiatic settlers on the one hand and the indigenous African population on the other, for the first see in the rising African demand for a share in the political and economic life of the continent a threat to their position, while the latter see in the presence of the settlers a barrier to their progress.

It is no wonder that Africa in recent years has caught the attention of scholars concerned with problems of political, economic and social change, or that many segments of the American population are eager to inform themselves about African conditions.

It is in this context that the African Research and Studies Program has been developed at Boston University. Early in 1951 various members of the faculty of the University discovered that they had a common interest in Africa. From their discussions emerged the idea of an African Program at the University. A faculty committee was formed to explore the possibilities of instituting such a program. University sanction was obtained, and the Program came into existence in 1953 with the assistance of a five-year grant from the Ford Foundation to cover a portion of its costs. The remainder is carried by the University. Dr. William O. Brown was appointed as Director of the Program and set about the task of recruiting staff, formulating a policy to guide its activities, and building up research resources.

The Organization of the Program

The Program is interdisciplinary in character and operates within the framework of the social sciences. In both research and teaching it deals with the whole of Africa, with the exception of Egypt, but the emphasis falls upon

the analysis of situations and problems rather than upon an areal focus. At the present time the permanent staff consists of two sociologists (one of whom is also the Director), three anthropologists, one economist, and one political scientist, all of whom have a personal acquaintance with some region of Africa.

Each year the Program also has the services of a visitor who is attached to the University either for a semester or for the full academic year, and whose research interests supplement those of the permanent staff. These visitors also contribute to the teaching activities of the Program. In 1956-57, Dr. Grace Harris (Ph.D. in Social Anthropology, University of Cambridge), whose field research has been with the Teita of Kenya, was a member of the staff. In 1957-58, the Program shares with the Department of Government the services of Mr. Jeffrey Butler (M.A., Oxford University), Staff Tutor in the Delegacy of Extra-Mural Studies at Oxford University. His primary research interest is the study of the political development of the Union of South Africa. In 1958-59, Professor S. Fawzi, Head of the Department of Economics in the University of Khartoum, Sudan, will join the Program for a semester. The Program and the International Educational Exchange Service of the Department of State are making his visit possible.

From the beginning, the Program has had a dual purpose: the training of students in African studies and the provision of a research resource for scholars whose interests are focused on Africa as an area of study. Members of the permanent staff and the visitors attached on a yearly basis are engaged in both research and teaching; other scholars come to the Program to use its library and to consult with its staff.

Teaching

The teaching activities of the Program are at the graduate level and take place within the context of the academic departments to which members of the staff are also attached. The University does not grant a degree in African Studies. Students who wish to take work in the African field and at the same time work for a degree are required to register in one of the departments of the University and to satisfy the degree requirements of that department. A portion of their course work can then be taken in the area of African studies through courses provided by the Program staff or by other members of the University faculty. In 1957-58, thirty hours in seminars and lecture courses were offered by members of the Program staff alone. The staff also give a considerable portion of their time to meeting the needs of individual students through directed reading or research courses. Courses are given in the following departments: Economics, Geography, Government, History, and Sociology and Anthropology. Members of the Program staff also contribute to the general work of the University by offering courses in their disciplines which are not related to the African field.

It is difficult to estimate the number of students who are at Boston University because of their interest in Africa. Many who take courses with members of the Program do so while pursuing other academic goals. Each year the Program awards a number of fellowships to students who wish to work for the M.A. or Ph.D. with a specialization in the African field. A number of students also come without the aid of fellowships. In addition, each year the Program supervises the work of some students who are not registered for a degree but who come for concentrated work in the African field. 1957-58 was the third year in which the United States State Department has sent two of its officers to the Program for such training. Usually these men have had some previous experience in the consular service in Africa and expect to be stationed there again upon completion of their work at Boston. Each year the Ford Foundation gives fellowships in its areal training program to young scholars who wish to do research in Africa. Some of these scholars are given an opportunity to spend some months at an institution specializing in African Studies before they start work in Africa. A number of them come to Boston each year to work at the Program. Recently the Ford Foundation has made available fellowships for those already engaged in teaching to permit them a year of study at an African Program in the United States. Several have indicated that they plan to spend their year at the Boston University Program.

Library Resources

To cater both to the ordinary student and to the scholar engaged in research, it has been essential to build up library holdings of material dealing with Africa. When the Program started, the University library had little of this specialized material. Today it has one of the best collections in the country though it is still only in the process of formation. By October 1957, the Program had added 3858 books and 2000 documents to the library holdings. The number of journals and series dealing with the area had risen from 26 to 170; 22 newspapers were being regularly received. Since October the collection has continued to grow, and the next inventory should show a considerable increase, especially in the document section. In the last few months, for instance, the documentary materials on East Africa have been very largely augmented. Periodicals and newspapers give an extensive coverage of the different regions of Africa both for current affairs and for current research. The Program is also making a special endeavour to obtain the official publications of all the African countries. Already it has a good coverage for some areas; for others, because of special problems, it is still weak.

Creating a specialized areal library is no easy task; many of the difficulties are formidable. Important works may be out of print and must be traced through secondhand dealers. Where publications are of foreign origin, as are most of those dealing with Africa, it frequently requires a good deal of detective work to find a channel through which they may be ordered. Pamphlets,

books, and other materials printed by local African presses, even when these are government presses, are often unknown outside their country of origin. Local presses may not be accustomed to handling overseas orders. Considerable credit must be given to the staff of Chenery Library for its willingness to cope with the many problems involved both in obtaining materials and then in handling and cataloguing the items when they finally arrive. The Program staff is also actively involved in the search for material. On their visits to Africa, various members have traced down publications and established contacts to ensure that new publications find their way to the Boston University Library without undue delay.

In addition to the library holdings, the Program is building up a small collection of other research materials. It already has available a collection of maps, and in recent months it has begun a collection of recordings of African music and folk tales. These last are now being catalogued by Dr. Milloy Miller of the Department of Music.

Research

Much of the work of the Program is oriented towards research. Its staff is frequently consulted in the planning of research projects by scholars from other universities, and it has also assisted research activities of other members of the Boston University faculty. Permanent members of the Program staff are also directly involved in research, sometimes individually, sometimes in collaboration with one another or with colleagues at other institutions who share common research interests.*

Recently the Program has taken a step to increase its contributions to African research. It is inaugurating a new series of occasional papers under the title *African Research Studies*. In it will appear the work of staff members and of Africanists at other institutions. The series will have a dual purpose: to present informed discussions of current trends in Africa; and to contribute to basic research in the disciplines which are today drawing an increasing body of data from the African area. *African Research Studies* will be the first scholarly publication in the United States to devote itself exclusively to African studies.

Other Program Activities

Although the training of students in African studies and the forwarding of scholarly research are the primary aims of the Program, its staff are engaged in many other activities which can only be described as providing a clearing-house through which information about Africa and African research is given wider currency and also through which overseas scholars and American scholars receive information about one another's activities. Staff members visit the various research centers in Africa and make contact with col-

*An article reviewing the research activities of the Program is scheduled for publication in a forthcoming issue of the *Journal*.

leagues in the field. They are also in close communication with scholars in Great Britain and on the continent of Europe. Personal visits and attendance at international conferences enable them to keep abreast of the work of overseas colleagues. To the Program comes a constant stream of overseas and American visitors who are concerned with African problems. Some of these join staff and students at the Program for informal discussions; others give public talks to a wider audience. Members of the Program's staff have also been closely associated with other organizations interested in Africa.

The Future of the Program

At the present time the Program is assessing the work of the last four years and planning for its future development. Throughout the United States interest in Africa is growing, and this is reflected in the growth of African Studies programs at many different colleges and universities. In planning for the future, the Program is attempting to relate its work in the most effective fashion to that of other institutions and to provide for the new needs which are emerging as scholars seek to coordinate their research and synthesize their research results. The Program feels that it is in this area that it can make the most effective contribution to the development of African studies in the future. It is now considering ways and means by which the Program can advance to perform such a role for Africanists and for the many interested bodies and individuals who seek the results of African research though they are not engaged in research themselves.

The Relation of Electrochemical Potential to the Degree of Sintering*

BENNETT BOVARNICK

Ph.D. in Physics, Boston University Graduate School, 1958
Chief of the Sintered Metals and Ceramics Branch
Rodman Laboratory, Watertown Arsenal, Watertown, Mass.

ALTHOUGH powder technology is an old and long practised art,[1] it was only recent decades that saw fundamental scientific investigations of its several phases undertaken. The greater portion of the effort has been on the study of the sintering phenomenon, the major step in the consolidation of powder to dense material. The many investigations have led to several variant hypotheses to explain the phenomenon but, to this time, none of these has

This paper is based on a dissertation submitted to Boston University Graduate School in partial fulfillment of the requirements for the Ph.D. in Physics. The author wishes to thank Dr. J. J. Josephs, First Reader; Dr. A. Siegel, Second Reader; and the late Dr. H. S. Joachim, Guest Reader, for their guidance of this work.

been universally accepted.[2] The incomplete understanding of the physical mechanisms and forces of the sintering process is reflected in the lack of a clear definition. For the purposes of this work the meaning of sintering has been restricted to the process in which physical bonds are established under the influence of temperature and time between neighboring powder particles initially in mechanical contact.

The study of sintering has been seriously retarded by the absence of a test based on a physical property which has a direct correlation with the extent of sintering achieved. Several physical properties have been studied in the past[3] in attempts to establish correlation between a property and the extent of sintering, but only limited success has been realized. In spite of the limitations of previous methods, no efforts had been undertaken for the investigation of the feasibility of measuring changes in the electrochemical potential of sintered specimens as an indication of the degree of sintering. This paper will describe the principles and techniques employed in a study of the relationship between the electrochemical potential and the degree of sintering and other physical properties.

Consideration of a system of independent powder particles in mechanical contact leads to the conclusion that the energy of the system should be at a maximum in this state compared with the energy of any other state. As the state of the system changes from independent particles to physically bonded aggregates of particles, the energy will be reduced. The changes of energy will be reflected in the thermodynamic energy of the system. The equivalence of electrochemical potential and thermodynamic energy, as expressed by the Gibbs-Helmholtz concepts,[4] suggested the study of the electrochemical potential to indicate changes in energy and degree of sintering.

Specimens for subsequent treatment and test were prepared from a high purity superfine carbonyl iron powder[5] with particles about 400 millionths of an inch in size. The powder was annealed in a hydrogen atmosphere. The specimens were compacted to shape under pressures ranging from 25,000 psi to 75,000 psi. The resulting densities were equivalent to 64, 70, 76 and 83% of the theoretical density of 7.86 gm/cc for solid iron. Some of the specimens at each of these densities were set aside for testing in the unsintered or green condition and the balance were sintered for various combinations of times and temperatures. The temperatures were 800°C, 1000°C and 1200°C (or 1470°F, 1830°F, and 2190°F). The times for sintering at each of the three temperatures were 1/2 hour, 1 hour, and 8 hours in order to observe both short time and long time effects. Including the unsintered samples, a total of forty different conditions were available for examination.

The experimental test design incorporated an electrochemical cell as the sensing device and a null balancing potentiometer circuit for observing the output of the cell.

The specimens were employed as electrodes in the cell, with an 0.1M ferrous chloride electrolyte and with a saturated calomel half-cell as reference electrode. Ferrous chloride was employed as the electrolyte in order to meet the requirements of reversibility with respect to the iron electrodes.[6] The electrode cell was maintained under a deoxidized nitrogen atmosphere. The deoxidized atmosphere was required to retard the oxidation of ferrous ions to ferric ions so that cell stability could be maintained for periods exceeding ten days. Auxiliary components included a vacuum pump to remove dissolved air from the electrolyte, and a back pressure trap to prevent diffusion of oxygen into the cell through the gas train exhaust.

In general, specimens exhibited similar electrode behavior. The potential increased rapidly from an apparent zero at the time of immersion to values approaching the equilibrium value of the specimen in about 30 to 60 minutes. The observed time required for the rise of the potential is attributed to the delay for capillary penetration to the interior of the specimens. Many specimens were maintained in the cell for extended periods of time to determine the extent of any further changes. After one thousand minutes of immersion, any subsequent change in potential by holding for more extended periods such as up to 10,000 minutes was less than 0.01 volt.

For convenience in discussion, the specimens may best be considered in two separate groups: unsintered and sintered. The unsintered specimens attained a uniform value of potential (Table I) essentially independent of their initial density and, by the same token, independent of the mechanical load applied during compacting.

TABLE I

Electrochemical Potential of Unsintered Specimens

Packing Density (gm/cc)	*5.0*	*5.5*	*6.0*	*6.5*
Potential (volt)	0.719	0.717	0.719	0.722
	0.716	0.720	0.723	0.723
	0.724			0.717
				0.724
				0.717

The average value for all packing densities is 0.720 volt with a range of 0.004 volt. The potential of these specimens was, within the reliability of the system, 0.720 volt with respect to the saturated calomel electrode. The potential should be stated as that attained for hydrogen annealed carbonyl iron powder with the nominal size of 10 microns and a carbon content less than 0.01 percent. The equivalence of the electrochemical potential for all the unsintered specimens is interpreted to mean that the subsequent changes of the potential in sintered specimens are not dependent upon the total internal surface area. This is recognized from the fact that the unsintered material

was formed to four different packing densities with four different internal surface areas, which are approximately in the ratio of 10:11:12:13.

For ease of comparison of the potential of sintered specimens, the several conditions employed with each sintering treatment may be discussed as separate groups. In each group, the measured potential decreased as the severity of the sintering conditions increased. The decrease observed in the potential may be taken as indicative of an increase in the stability of the configuration of crystal structure and surfaces in the sintered specimen. The dependence of the potential upon the variables of the sintering treatment are summarized by the following remarks: with respect to temperature, the potential was lowest for specimens held at 1200°C (2190°F) and highest for the 800°C (1470°F) series; with respect to time the potential was lowest for samples heated for 8 hours and highest for the half-hour group; with respect to packing density, the sintered specimens with the highest initial packing density (or lowest porosity) had the lowest potential, the potential of the specimens increasing with decreasing packing density.

The minimum potential measured was 0.62 volt with respect to the calomel electrode for a specimen with an initial packing density of 6.5 gm/cc held for 8 hours at 1200°C (2190°F), the most severe sintering treatment. The maximum value obtained against the calomel electrode was 0.76 volt for specimens held for only 30 minutes at 800°C (1470°F).

The behavior exhibited by the group of lightly sintered specimens was not as expected. Instead of decreasing from the potential of unsintered material, the least sintered specimens indicated an initial increase to the peak value of 0.76 volt. The potential of specimens with more severe sintering conditions was found to be less than the 0.76 volt, and decreased monotonically to the minimum of 0.62 volt. An explanation for the increase of potential with light sintering treatments is readily suggested. Chemisorbed oxygen atoms are occupying the sites of higher energy, these having been the first to participate in the oxidation of the surface. The removal of the oxygen by the sintering atmosphere exposes these sites. The subsequent decrease of potential shows that the atoms have relocated to more stable positions.

The specimens were also tested for density, mechanical strength, and metallographic structure. The sintered densities ranged from a minimum of 5.32 gm/cc to a maximum of 7.03 gm/cc. For a given processing schedule, the sintered density increased with the variables of the treatment except for one condition. The decrease in density of the material sintered at 1000°C (1830°F), attributed in the literature to the crystallographic transformation from alpha to gamma iron, is a partial explanation of the failure of density as a criterion of sintering.

The results obtained in the tensile strength tests of specimens subjected to the 36 sintering conditions ranged from a minimum on the order of 10,000

psi for the least sintered specimens to a maximum on the order of 30,000 psi for the most severely sintered specimens. The range of strength is in agreement with the commonly reported values.[7] The strength increased with each of the variables of the sintering treatment and, generally, may be said to increase with the severity of the sintering treatment.

A metallographic examination was conducted on specimens for all sintering treatments and unsintered specimens as well. Specimens were studied at two conditions: a cut and polished cross section at 200 diameters and the same surface etched at 500 diameters. The photomicrographs showed the change in the character of the voids and dispersion of porosity with the changing conditions of the sintering treatment.

It was essential to determine the degree of correlation of the electrochemical potential of the sintered material with the treatment and the results of other types of tests. A good correlation would establish a basis for a new type of test which would permit the discrimination of sintered materials. The mechanical or tensile strength of sintered material is a property which is recognized as indicative of the state of sintering attained and hence was selected as a basis for the analysis.

A plot of electrochemical potential against tensile strength indicated essentially linear correspondence between these two properties. The plot has the characteristics of the line $E = -hS + b$ where E represents potential, S the strength, and h and b are constants whose values were determined as 6.78×10^{-6} psi and 0.830v. The coefficient of potential with strength was calculated as 0.94. The result indicates a high statistical correlation between the electrochemical potential and the tensile strength. Thus, the sufficient condition for correlation of the degree of sintering with the electrochemical potential has been satisfied. There still remains the need to show the nature of the correlation between strength and degree of sintering.

As a result of the correspondence between potential and strength, it seemed reasonable to contemplate the existence of a sintering severity function which might permit the prediction of strength and hence the potential of sintered material. The derivation of such a function, incorporating all the variables of the processing treatment, was undertaken. The functional parameter, P, was derived from the principles of rate process theory and diffusion laws,[8] and found to have the form $P = \frac{d}{d_s} t^{1/7} T^2 e^{Q/RT}$ where d/d_s is the relative density, t is time, and T is temperature. The plot of strength against the calculated values of P showed a linear relationship between the strength and the sintering severity parameter: $S = S_o P$ where $S_o = 7190$ psi. The calculated correlation coefficient between the experimental and predicted values of strength was 0.90.

In this way has been shown the necessary basis for correlation between

the electrochemical potential and the degree of sintering. The relation of the electrochemical potential was expressed by $E = -hS + b$. Coupling this with the relationship between strength and the sintering severity parameter, $S = S_oP$, leads to an expression between electrochemical potential and the parameter by substituting for S.

The result is $E = -E_oP + b$ where $E_o = 0.0487v$ and $b = 0.830v$. The correlation coefficient between the experimental and predicted values of the electrochemical potential is found to be the same as that for the correlation coefficient of the electrochemical potential with strength: 0.94. These results indicate a high statistical correlation between the electrochemical potential, E, the tensile strength, S, and the theoretically derived sintering severity parameter, P.

The major finding of the research is the degree of sensitivity of the electrochemical potential of the material to its particular history. It follows therefore that the electrochemical potential of crystalline metals is subject to control. Techniques based on those described herein may be employed for the investigation of the differences in electrochemical potential of various crystallographic planes in a lattice, the potential in the boundaries between crystals, and possibly extended to a measure of the potential due to the concentration of lattice dislocations, vacancies, and other irregularities in the interior of the crystals. These techniques may be expanded to investigate the continuous change in energy level of a system as it approaches and crosses allotropic transformation conditions and provide further insight into the phenomena involved in such transformations. It may be possible by means of these techniques to investigate the extent of lattice distortion induced by irradiation of high energy particles which are currently considered to induce effects similar to those of metallurgical cold working techniques. An investigation of the potential character of catalytic powders may lead to improved methods for understanding the difference between poisoned and unpoisoned surfaces. These applications are among the more obvious which come to mind upon review of potential uses of these techniques. Modifications of these techniques could readily be employed in industrial practice, primarily as inspection methods for discrimination between quality levels of material coming through a production line.

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Book Reviews

The Modern Researcher, by Jacques Barzun and Henry F. Graff. New York: Harcourt, Brace, 1957. 386 pages, $4.50.

A Guide to Graduate Study, ed. Frederic W. Ness. Washington, D. C.: Association of American Colleges, 1957. 335 pages, $5.00.

THE Modern Researcher is a book written to show the student interested in research how to find his materials, how to determine their significance, and how to communicate to others the information he discovers. It therefore attempts to accomplish in one volume what ordinarily requires a research handbook and a manual of style, and in addition gives the reader a discussion of some of the ideas governing all research.

Part One presents research as history, and discusses the basic techniques of scholarly investigation. Part Two treats the process of research in logical sequence and with considerable detail; the chapters on verification, handling ideas, and truth and causation are especially valuable, since few books treat these important matters significantly. Part Three, "Writing," is one of the clearest and most concise of the available discussions of writing for publication. The authors discuss organization, word choice, sentence structure, and revision — matters of which most beginning scholars mistakenly assume themselves masters — as well as the proper methods of citing and quoting.

The book is detailed and comprehensive; it is also well written: Drs. Barzun and Graff have themselves many of the stylistic virtues they ask the student to develop. In addition, their examples are carefully and wittily chosen, their use of sources intelligent, and their bibliography selective enough to be helpful to the beginner. The authors perhaps place too much emphasis on history, historians, and historical ideas; one may agree that research is historian's work and yet feel that the point is made too often in a work designed for a non-specialized audience. Some of the space might profitably have been given to a brief survey of book-making, printing, and analytical and descriptive bibliography. For basic information on these aspects of research, one must still turn to R. B. McKerrow, and others.

The bulk of *A Guide to Graduate Study* is an annotated alphabetical list of American graduate schools offering programs leading to the Ph.D.; the typical entry includes an historical note, sections on admission requirements and fees and first-year aid, and a list of the fields of study offered with a considerable amount of detailed information about each. For the prospective graduate student the editor includes a concise discussion of the nature and objectives of graduate study, and sections on who should go to graduate school, how one prepares for and finances graduate study, how one selects a graduate school, and what one should expect of graduate education.

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